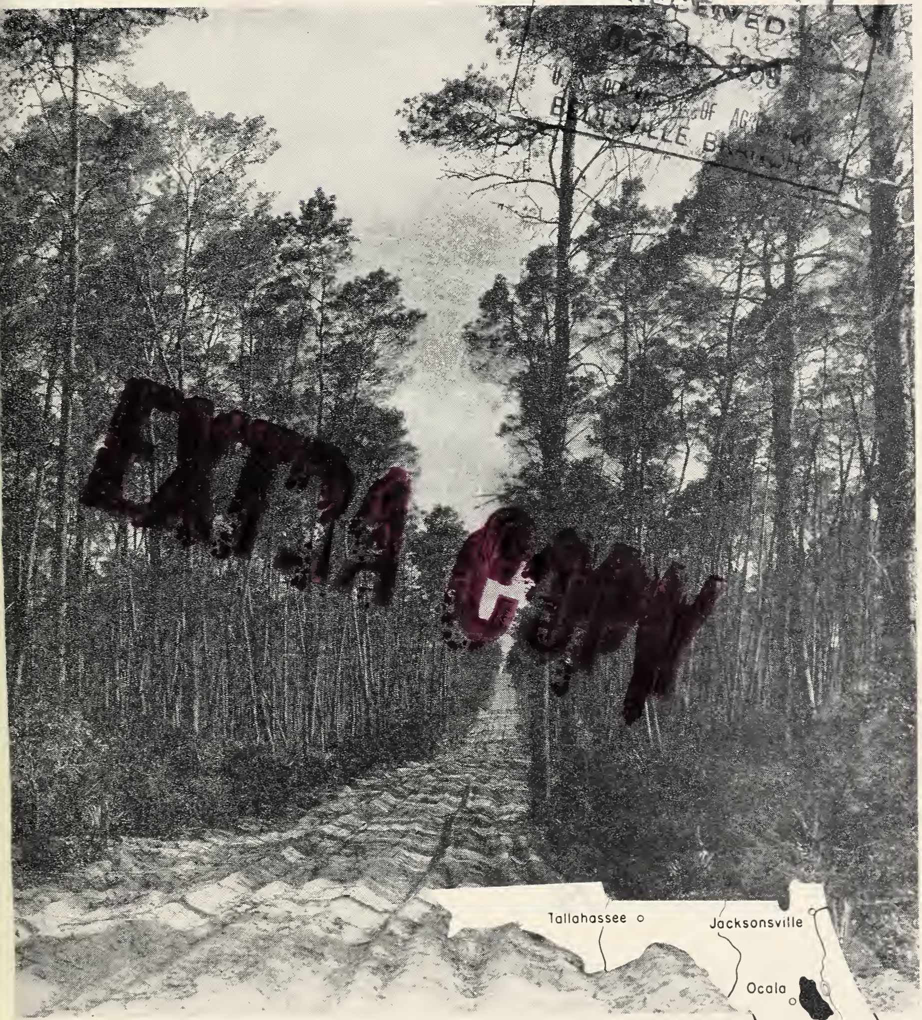
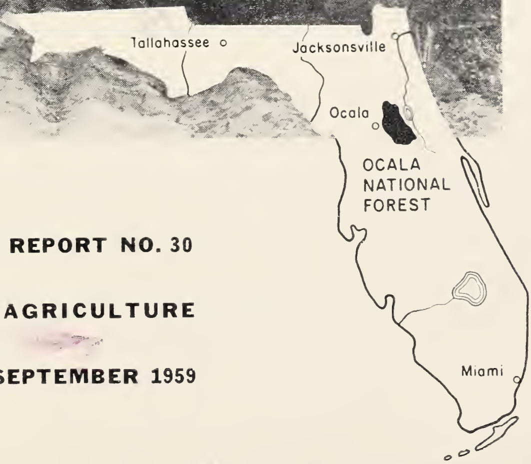
Sand Pine Regeneration

on the Ocala National Forest





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Cover photo: Typical stand of mature sand pine. F-225023

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Sand Pine Regeneration on the Ocala National Forest[1]

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INTRODUCTION

In Florida's Ocala National Forest, unmanaged stands of sand pine (*Pinus clausa* (Chapm.) Vasey) have regenerated for many years as a result of wildfires. When a killing fire sweeps through a stand of cone-bearing trees, the serotinous cones open and release tremendous quantities of seed. Dense stands of reproduction (fig. 1) usually

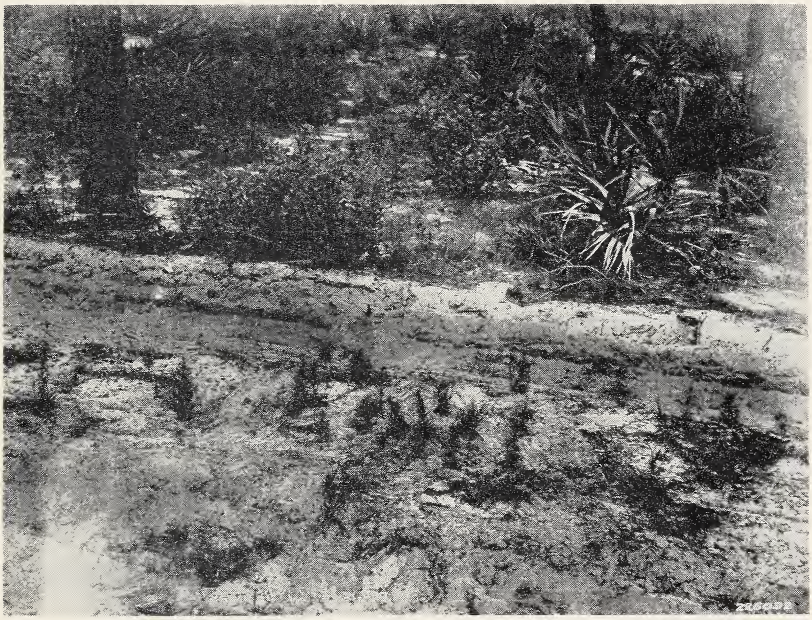

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FIGURE 1.—One-year-old sand pine seedlings established naturally on bare soil of a road through burned area. Seedlings were also abundant throughout the burn.

follow such fires. The standing trees, however, are killed and only a small part of the merchantable timber can be salvaged. Hence this method of reproduction has no place in forest management.

Sand pine is relatively short lived (70 years), growing to a height of 65 feet and maximum diameter of 18 inches. It grows in dense, even-aged, pure stands as a direct result of past fires. Cones are borne at an early age and frequently mature on 5-year-old trees. The species

[1] Research project on sand pine regeneration conducted by the Southeastern Forest Experiment Station and the Ocala National Forest, Forest Service, U.S. Department of Agriculture.

is similar to jack pine (*Pinus banksiana* Lamb.) and lodgepole pine (*P. contorta* Dougl.) in that the cones are very persistent and serotinous. Since an abundant crop is produced every year, each tree becomes a storehouse of seed. By the time a sand pine stand is 15 years old, seed production is great enough to restock the area, but only if a killing fire occurs. Thus, regeneration without killing fires is a problem.

The only large concentration of sand pine in the world is a block of about 210,000 acres in the Ocala National Forest in north-central Florida. The area was considered wasteland by the local people until 1940. Early settlers aptly named this area "The Big Scrub"—a name that persists today (*11*).[2] It was a favorite hunting and fishing ground for the early residents of north-central Florida, and such use continued after the area was proclaimed a national forest in 1908.

The species is also abundant locally in a narrow strip along Florida's east coast from St. Augustine southward to Fort Lauderdale. On the gulf coast, the southern limit is in the vicinity of Naples, in Collier County. Sand pine also occurs along the gulf coast of western Florida between Panama City and Pensacola, westward into Baldwin County, Ala., and on islands off the Florida coast (fig. 2). Trees along the gulf coast are often dwarfed, possibly because of salt spray.

[2] Numbers in parentheses refer to Literature Cited, p. 36.

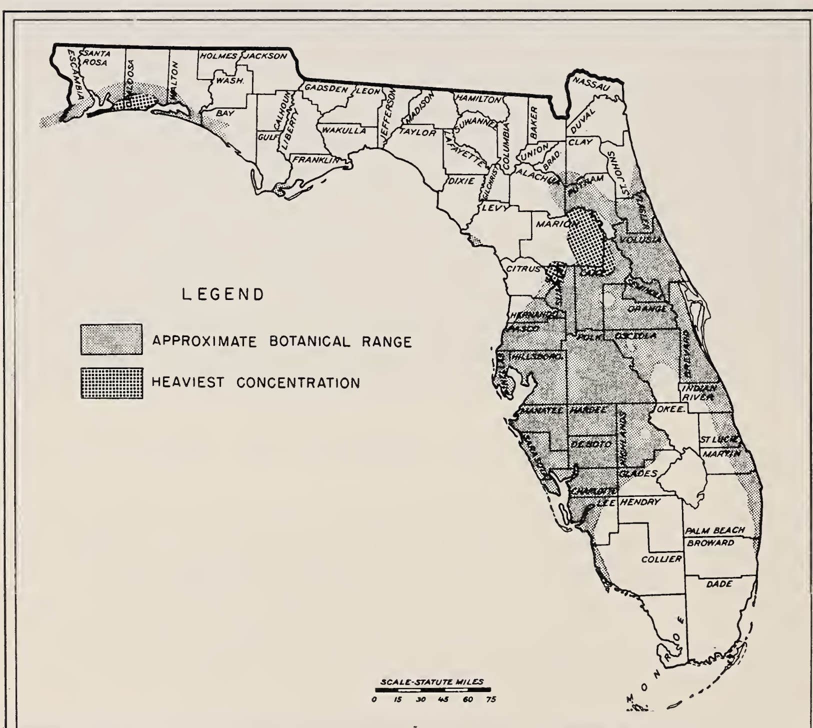

FIGURE 2.—Range of sand pine.

There is a distinct geographic variation in the percentage of closed cones. The percentage is very high in peninsular Florida and considerably lower in western Florida. Little and Dorman (*5*) found no morphological differences in sand pine between these two localities, but proposed common names to distinguish the two races. They gave the name *Ocala sand pine* to the typical trees with closed cones occurring in peninsular Florida and *Choctawhatchee sand pine* to trees with open cones in western Florida. Ocala sand pine has practically always occurred in even-aged stands, whereas Choctawhatchee, because of seed dispersal from open cones, sometimes develops uneven-aged stands.

Shrubby species associated with Ocala sand pine consist primarily of rosemary (*Ceratiola ericoides* Michx.), saw-palmetto (*Serenoa repens* (Bartr.) Small), scrub-palmetto (*Sabal etonia* Swingle), and scrub oaks. The common scrub oaks found in the Ocala region are Chapman oak (*Quercus chapmanii* Sarg.), sand live oak (*Q. virginiana* var. *maritima* (Michx.) Sarg.), and turkey oak (*Q. laevis* Walt.) (*7*).

One geological formation, the Citronelle, supports the sand pine type and is composed of sand, gravel, and occasional strands of clay. All the sand is classified as fine textured and well drained, with three distinct soil series: St. Lucie, Lakewood, and Kershaw. Beal [3] found the permanent wilting percentages to be 0.73, 0.65, and 0.63 for the Kershaw, Lakewood, and St. Lucie fine sands, respectively.

The climate in north-central Florida is characterized by hot summers with abundant precipitation, and mild, rather dry winters. Annual rainfall is 53 inches, of which approximately 60 percent occurs in the 4 months from June through September (fig. 3).

When the Ocala National Forest was first established, most of the sand pine stands were so young, as a result of frequent fires, that they were unmerchantable. Under the administration of the U.S. Forest Service, the degree of protection from fire gradually increased. Hence, more and more stands of sand pine reached merchantable size. The discovery in 1932 and 1933 that good sulfate pulp could be obtained from sand pine opened the way for profitable utilization of the species.

In 1938, a survey [4] showed that there were 272,000 cords of merchantable sand pine pulpwood on operable areas within the Ocala National Forest. At that time an annual harvest of 22,000 cords of pulpwood was proposed. In 1940, the first sand pine sale was made, but the proposed annual harvest was not reached until 1946, when the postwar boom in the pulpwood market occurred. Since that time annual cuts have been increasing. Nearly 200,000 cords of sand pine wood were removed from the Ocala National Forest between 1940 and 1953, but because of tremendous ingrowth of the younger age classes, more than 700,000 cords of merchantable wood still remain. Sustained annual cuts of 35,000 to 40,000 cords may be possible as the

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[3] Beal, J. F. A STUDY OF THE WILTING PERCENTAGES OF SANDY SOILS OF THE OCALA NATIONAL FOREST AND THEIR EFFECT ON THE REGENERATION OF SAND PINE. Master's thesis, Univ. of Florida. 1951.

[4] Craig, D. A. MANAGEMENT PLAN—SAND PINE WORKING CIRCLE—OCALA NATIONAL FOREST. 1938. (Manuscript on file at the Ocala National Forest, Ocala, Fla.)

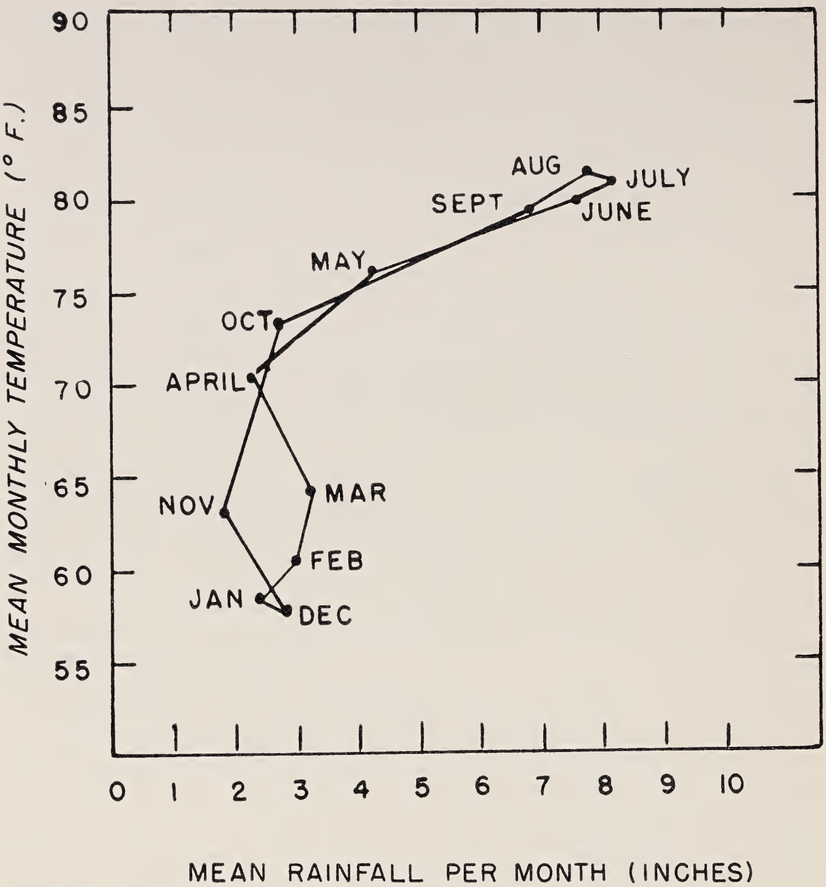

FIGURE 3.—Climograph for Marion County and Ocala National Forest, Fla., 1915–38.

age class distribution improves and the regeneration problems are solved.

These regeneration problems are by no means simple. After being cut, a sand pine stand seldom regenerates adequately without supplemental treatment. Hence, many areas cut in the past were taken over by scrub oak and other scrubby species. In addition to these problems of natural regeneration, about 30,000 acres of nonstocked land in the Ocala Forest are without a seed source and in need of artificial regeneration. Of this area, about 20,000 acres had been burned before trees reached seed-bearing age. When this happened, sand pine did not come back, and scrub oak again took over. Cutover lands that failed to regenerate, stands that died of old age, and tracts that are poorly stocked comprise the remaining 10,000 acres. Development of a satisfactory method of artificial regeneration was necessary if these denuded acres are to be productive again.

Although no formal research on the regeneration of sand pine had been attempted prior to 1949, many trials had been carried on in preceding years by service personnel. These trials formed the basis for many of the research studies. Preliminary information on seedfall, cone opening, and seed viability was first obtained and examined for possible causes of regeneration failures. A series of small-scale tests to determine critical factors affecting germination and survival followed. Finally, in an attempt to modify some of the controllable factors limiting sand pine reproduction, some large-scale trials of regeneration methods were made.

The studies described here were carried on during the 7-year period from 1949 to 1956. The conclusions and recommendations remain applicable.

PRELIMINARY STUDIES

Natural Seedfall

To find out just how much seed, if any, is released normally, seed were trapped and counted during 1950 in sand pine stands of varying age and density (table 1). About 50 percent of the seed released fell during May, June, and July. Only 22 percent of all the seed that fell was viable. The greatest number of viable seed recorded was 16,000 per acre in a stand cut over the previous year under a seed-tree system whereby about 10 seed trees per acre were left, each selected for its cone-producing ability and the presence of some open cones. All indications, however, were that natural fall of viable seed from residual standing trees is scant with any system of cutting.

Table 1.—*Sand pine seedfall for different stand conditions, 1950*

Stand condition [1]	Basal area of trees 5 inches d.b.h. and over	Trees per acre with open cones	Total seed per milacre	Viable seed [2] per milacre	Period of greatest seedfall
	Square feet	*Number*	*Number*	*Number*	*Month*
Seed tree	11	5	42	16	June–October.
Diameter limit	24	1	24	2	May.
Shelterwood	20	4	44	8	June.
Clear-cut strip	5	1	24	7	June.
Uncut strip (sawtimber cut, pulpwood left).	31	3	29	5	June.
30- to 40-year-old stand.	.49	4	18	3	June.
50- to 60-year-old stand.	41	5	47	8	July–September.

[1] Age of residual trees 40 years, unless otherwise indicated.
[2] Based on catch in four seed traps of ¼ milacre each.

Seed Release After Wildfires

Because killing wildfires have been the major factor causing release of seed from the serotinous cones, some magazine writers have said that sand pine has to kill itself to be reborn. Regeneration following wildfires in stands of cone-bearing trees has usually been adequate, but failure is possible if the fire occurs at a time when conditions for seedling establishment are unfavorable. Evidence of such failure was obtained in studying one fire for data on time and amount of seed release, viability of seed, time of germination, and number of seedlings established (*1*).

On February 19, 1950, a wildfire, hot enough to scorch needles and kill trees, swept through about 200 acres of even-aged, 40-year-old sand pine in the Lake Dorr area of the Ocala National Forest. Four seed traps with a surface area of one-eighth milacre each were set out 24 hours after the fire. Seed counts were made 1, 7, 17, and 21 days after the fire. On the first day, counts were also made of the seed in sample plots on the ground at the time the traps were set out. Petri-dish germination tests were used to test seed viability. These collections were followed by periodic observations of regeneration and changes in environmental conditions.

Seedfall began less than 9 hours after the fire, and at the end of 3 weeks about 1,092,000 seed per acre had fallen in the dense stand (fig. 4). In the open stand, approximately 420,000 seed per acre were released during the same period. Forty percent of the fallen seed was viable; seed falling during the first week was of better quality than seed released later. Seed dispersal appeared to be almost completed by the end of the third week, when the traps were removed to avoid damage from a salvage cutting operation.

Germination on the burned area was first observed on April 12, 1950, 50 days after the fire. Examinations on April 25 indicated approximately 1,000 sturdy seedlings per acre. By May 20, however, high surface soil temperatures, drought, and possibly other influences had wiped out the entire crop of reproduction. Rainfall during a 30-day interval in April and May was less than one-half inch, and soil surface temperatures were as high as 150° F. Also, low vegetation had not grown enough to provide much shade, and shade from dead trees was reduced considerably when the pulpwood cut was made.

After the first wave of seedlings had been wiped out, almost no seed were visible on the surface of the ground, but the presence of buried seed in the soil was suspected. For this reason, an estimate was made of the number of buried seed per acre from data on four 1-milacre sample plots in the dense stand. Soil was removed from each plot to a depth of 1 inch and passed through a screen to separate the seed. Seed counts showed that about 269,000 seed per acre were in the soil 3½ months after the fire. A cutting test revealed that only 14 percent, or about 37,000 seed per acre, was sound.

The limited samples obtained in this study indicate that over 90 percent of the dispersed seed were not accounted for 3½ months after the fire. Of the 10 percent recovered, nearly all were buried in the sand. The seeds not accounted for included those consumed by ants, birds, rodents, and those that may have lost their viability as they lay on or in the ground. The loss to birds was probably large, since many birds were seen on the burned area and some were trapped.

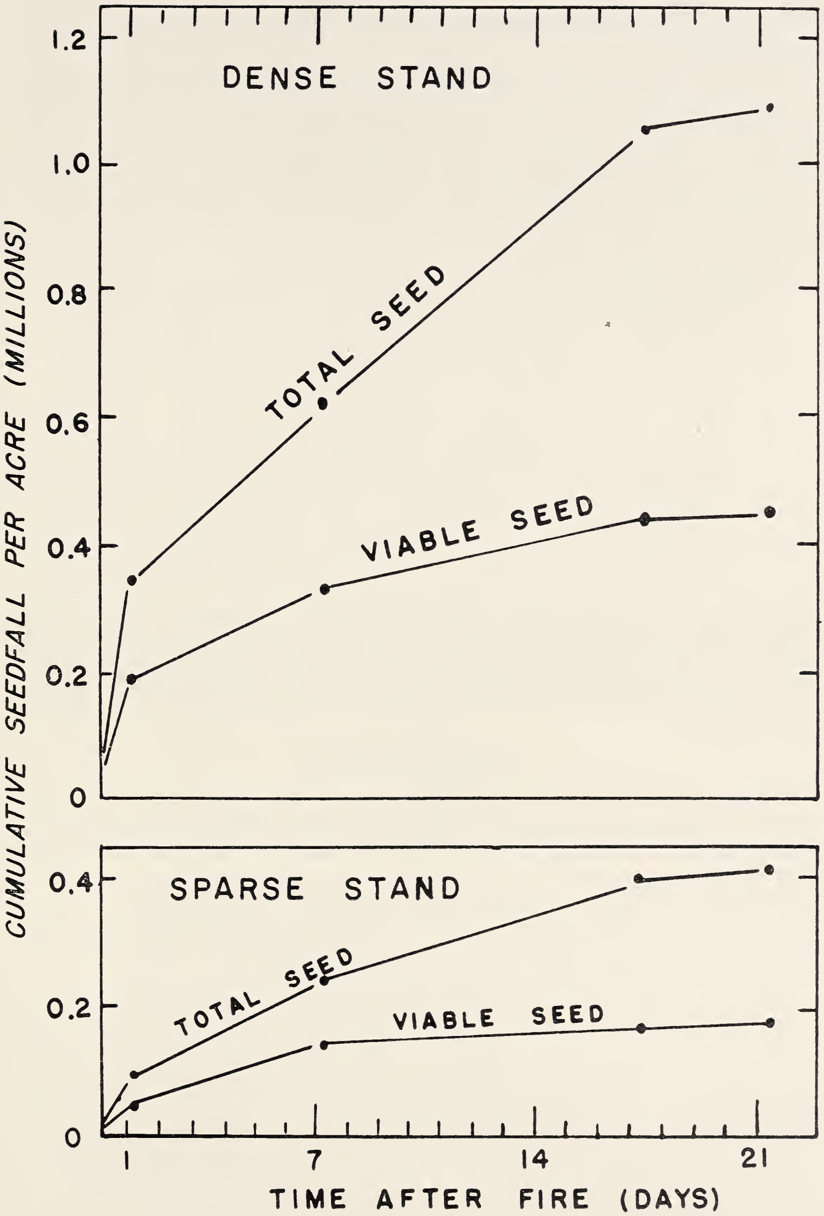

FIGURE 4.—Rate of seedfall after a fire, February 1950.

Mourning doves (*Zenaidura macroura carolinensis* (Linnaeus)), towhees or chewinks, *Pipilo erythrophthalmus* (Linnaeus)), and blue jays (*Cyanocitta cristata* (Linnaeus)) were the most prevalent. Observations were not sufficiently extensive, however, to determine

whether birds usually account for such extensive losses to seed on burned areas.

Some of the seed that was buried in the sand germinated during the following winter, but less than 25 percent of the milacres supported established seedlings 3 years after the burn. Such stocking is not adequate and is well below the stocking usually obtained after fire. Also unusual was the February 19 date on which the Lake Dorr fire occurred. Fire records for the 25-year period 1927–52 for fires of 10 acres or more in the sand pine type show that most fires have taken place in May, as follows:

Month of occurrence:	*Fires (number)*	*Proportion of total (percent)*
January	1	2
February	6	12
March	8	15
April	6	12
May	16	31
June	5	10
July	3	5
August	0	0
September	0	0
October	4	8
November	3	5
December	0	0
Total	52	100

These late spring and early summer fires are probably the ones that account for the dense stands existing today. Fires in January and February are not common, but the Lake Dorr example disproves the local belief that dense stands of reproduction will follow fire regardless of season.

Cone Opening

When sand pine trees are killed by fire, the cones open and seed falls. A fire not hot enough to kill, however, seldom causes cones to open. Is it the drying resulting from death or the heat of the fire that opens the cones?

In 1931, Hadley [5] answered this question by observing cones on girdled trees. The girdled trees died a lingering death, and some survived for 2 years, but the cones remained closed. Obviously then, heat from a head fire is the direct cause of cone opening.

Cones on both tops and lopped branches of harvested trees often open as a result of reflected solar heat from the ground. In 1950, cones on branches cut in April and July released 80 percent of their seed within 7 weeks. This time interval was quadrupled in November and February. The time required for seed release from cones on cut branches laid on seed traps was as follows:

Date of cutting:	*Seeds released per cone (number)*	*Time required for 80 percent of seeds to drop (weeks)*
Apr. 25, 1950	20	6
July 25, 1950	23	7
Nov. 1, 1950	25	31
Feb. 1, 1951	29	27

Age of cones had no significant effect on rate of opening.

[5] Hadley, E. W. sand pine reproduction studies. 1932. (Ocala National Forest files.)

Since these cones and branches were on top of screened seed traps that reduced the reflection of surface temperatures somewhat, a similar test was made in 1951 and 1952 to determine the rate of cone opening with and without shade at different times of the year and at different heights above the ground. No traps were used, and the cones were exposed to natural moisture and temperature conditions. The results, as follows, indicated the same general trend of time required for cone opening as that for cones and branches over seed traps.

	Time required for 50 percent of cones to open at three heights above ground		
Date of cutting:	*0–1 feet (weeks)*	*1–3 feet (weeks)*	*4–6 feet (weeks)*
Apr. 12, 1951	3	4	5
July 18, 1951	3	4	4
Oct. 18, 1951	26	36	36
Feb. 8, 1952	10	18	-----

The rate of cone opening on cut branches under shade, however, was very much retarded when compared with that in the open. More than 90 percent of the shaded cones 2 feet and 5 feet above the ground remained tightly closed even through some of the hottest summer weather. Cones above the ground were somewhat slower in opening than those directly on the ground and often did not open completely.

Extraction of sand pine seed from closed cones can also be accomplished by artificial heat. Kingsley [6] found that oven temperatures of 140–150° F. for 4 hours opened cones from the past 5 crop-years. Extraction temperatures up to 170° for a period of 2 hours or less had little effect on viability. Other investigators (*10*) report a yield of 75,000 cleaned seed per pound.

Viability

The persistence of cones on sand pine causes an accumulation of cones of many ages on one tree. To determine the change in seed viability with increasing age of cones, petri-dish germination tests were made in January 1950 on seed from the cone crops of 1949 through 1945. Seed viability on a basis of total extracted seed decreased rapidly with age of cones. But this apparent loss of viability cannot be attributed entirely to cone age, because it is also influenced by the rather erratic fluctuation in soundness of the new seed crop from year to year (fig. 5).

The percentage of sound seed in any crop depends primarily on conditions at the time of pollination and during the 2-year maturation period. Consequently, loss of viability attributable to length of storage in the cones on the tree can be estimated by basing viability percentages on sound seed only (fig. 6). Here a definite downward trend is apparent in viability of sound seed with increasing age. This relationship is based on viability as determined in June of 1950 on seed from the previous five annual crops.

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[6] Kingsley, C. E. Report on the extraction and germination of sand pine seed. Six ounces of cleaned seed were obtained from a bushel of fresh cones, and only 2 ounces from a bushel of 4-year-old cones. 1948. (Report on file at the Ocala National Forest, Ocala, Fla.)

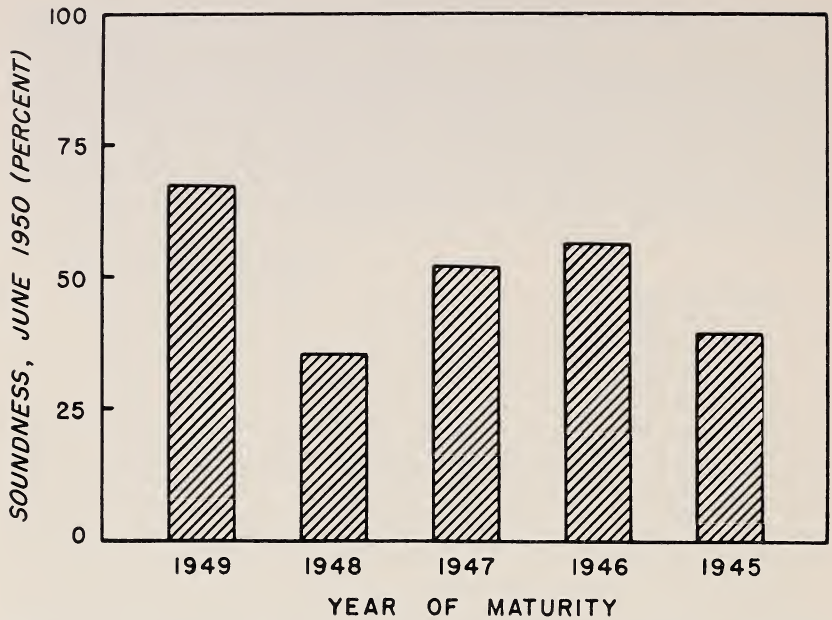

FIGURE 5.—Proportion of sound seed, as determined in 1950 from the previous five annual cone crops.

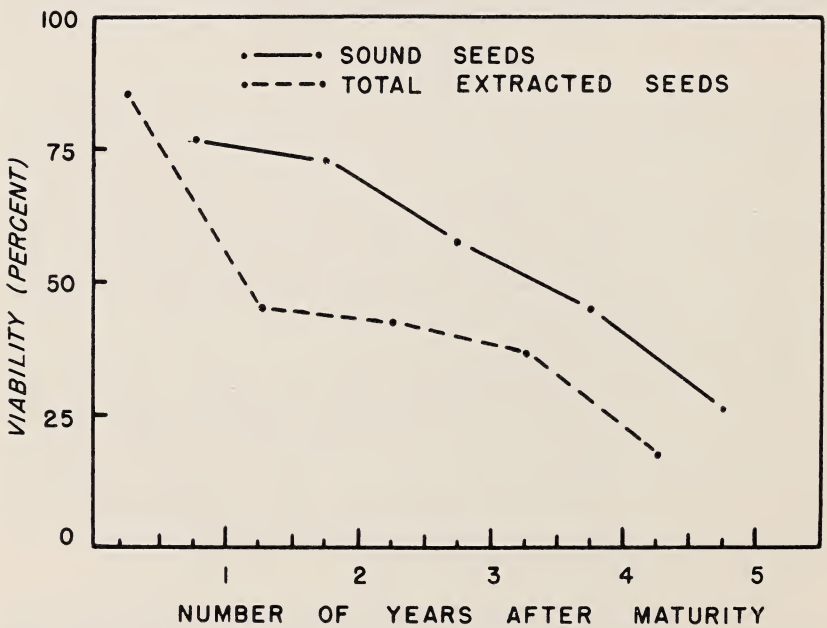

FIGURE 6.—Viability in 1950 of sand pine seeds from the previous five annual cone crops.

INTENSIVE SMALL-SCALE TESTS TO DETERMINE CRITICAL FACTORS AFFECTING GERMINATION AND SURVIVAL[7]

Thus far we had established the existence of ample supplies of viable seed and demonstrated the feasibility of using summer heat reflected from the ground to open cones on lopped branches. The next step was to determine the effect of some of the controllable factors affecting germination and survival. In 1950 an intensive, small-scale study was started on the effects of time of seed release (sowing date), shade, protection from rodents and ants, and removal of litter layer on germination of seed and survival of seedlings.

Two cleared blocks were established on an old double burn within the sand pine type (fig. 7). One block was kept free of ants and other insects by intermittent use of a 5-percent chlordane dust. No chlordane was applied on the other block, and no attempt was made to control insects therein. Within each block, four subblocks were established at random to represent the four sowing dates—spring, summer, fall, and winter. Each subblock included 18 randomly spaced plots (fig. 8), each 5 feet square, including a border strip. All factorial combinations of three surface conditions, two shade conditions, and three variations of protection against animals were tested. On an area 21 inches square within each plot, 300 sand pine seeds with an average viability of 45 percent were scattered. To insure uniformity, the environmental variations specified for each plot were constructed artificially.

Intact sections of the litter layer from nearby stands of sand pine were placed on all plots designated for a pine litter or burned litter cover. The burned litter cover was then formed with a blow torch. Bare mineral soil was exposed on the remaining plots by raking.

Protection from rodents and birds consisted of 4-mesh hardware cloth shaped into 21-inch squares with sloping sides about 8 inches high (fig. 9), buried to a depth of about 2 inches. Two degrees of such protection were used: One set of plots was protected with these rodent screens only during the period of germination; when germination was completed, as determined from seedling counts, the screens on this set of plots were removed. On the other set of plots, the rodent screens were left in place for 1 year after sowing. The comparison of these two degrees of protection was made to detect possible browsing damage from rabbits or other fauna on young seedlings.

Shade was provided by two layers of 16-mesh galvanized screen. These layers were fastened to the tops of the rodent screens; on plots without rodent screens they were suspended 6 inches above the ground by wire pins at corners of the plot.

Germination and survival counts were made weekly following the sowing dates. Seeds were counted as germinated when the hypocotyl appeared above ground and were staked with toothpicks so that seedling mortality and survival could be recorded. A thermograph was

[7] Material presented in this section was submitted by the senior author in partial fulfillment of requirements for Master of Science degree, New York State College of Forestry, Syracuse, N. Y.

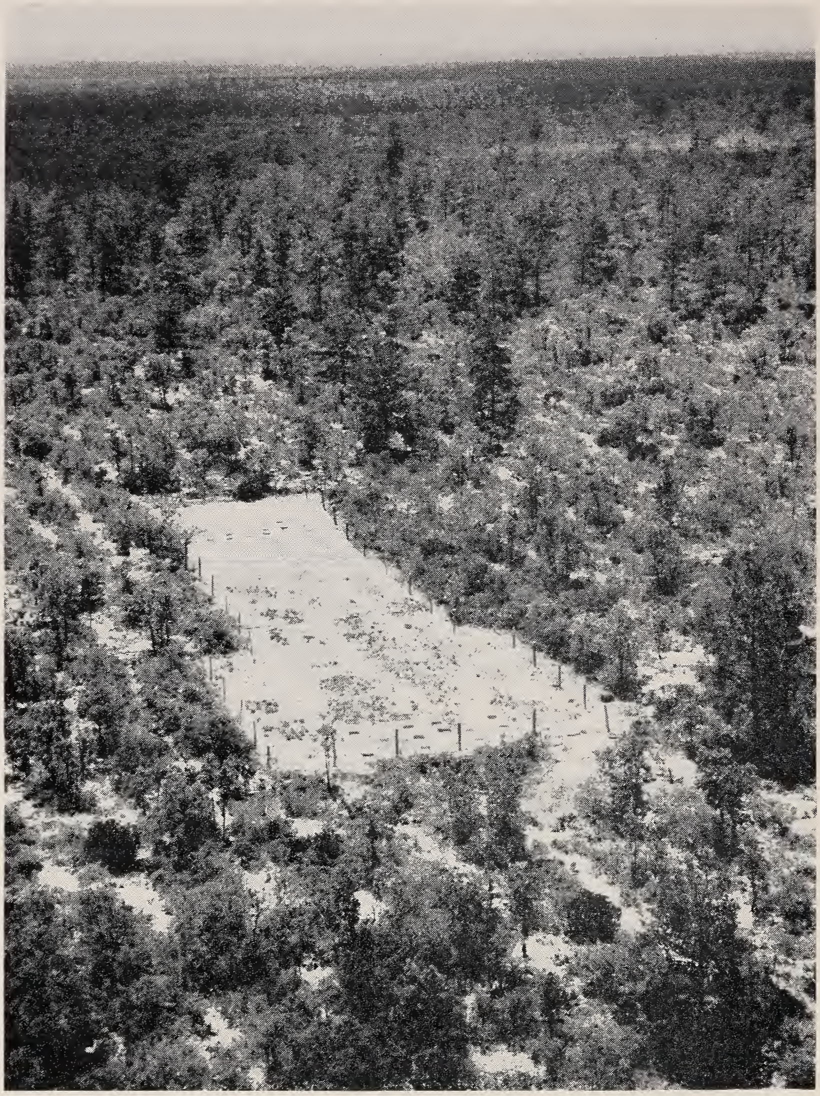

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FIGURE 7.—Site of germination-survival study, looking south from Central Tower, Ocala National Forest.

used to measure daily temperatures in the upper half inch of surface soil and in the litter layer. The metal casing of the thermograph bulbs, about one-half inch in diameter, was placed just below the surface and covered with enough sand to prevent direct exposure to the sun. For the litter surface, the bulb was placed above the soil, within the 1-inch litter layer. Daily rainfall was recorded in a standard Weather Bureau rain gage installed at a weather station adjacent to the plot.

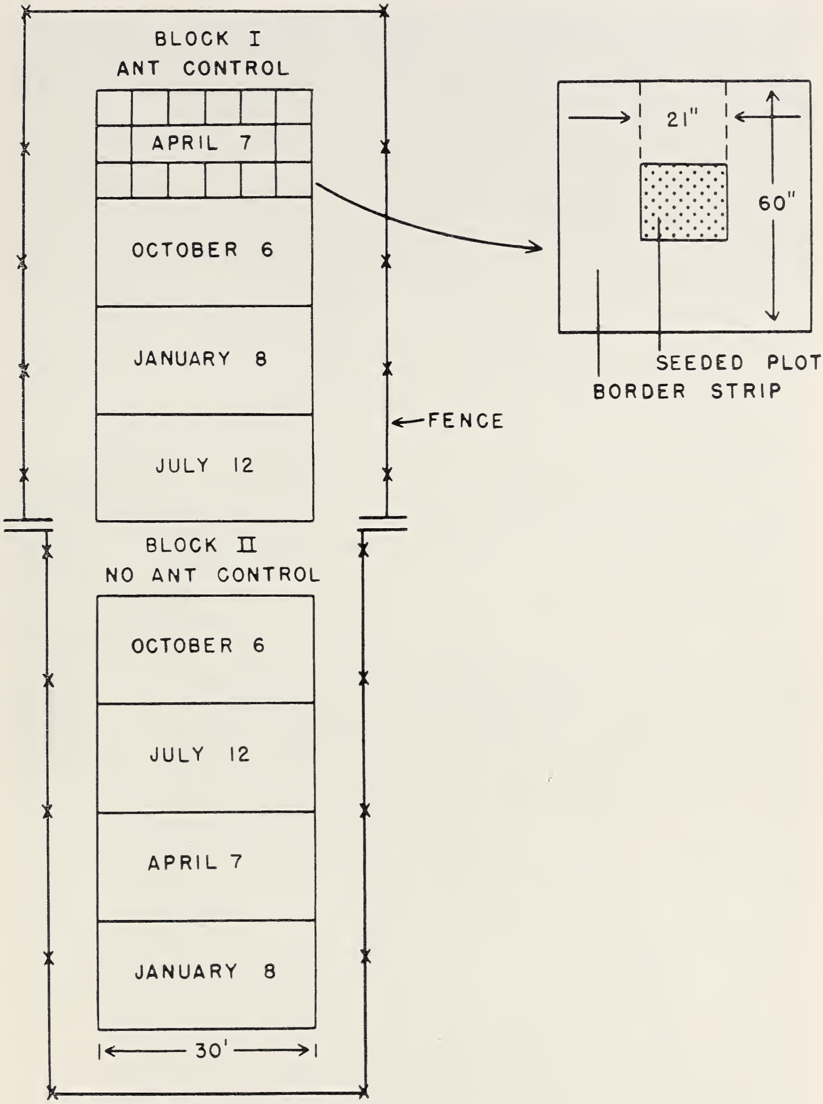

FIGURE 8.—Plot design for study of the factors affecting germination and first-year survival of sand pine seed and seedlings.

Ants, Rodents, and Birds

Germination in the ant-controlled block was eight times greater than where ants were not controlled (table 2). Several different species of ants were observed in the area, but the Florida harvester ant (*Pogonomyrmex badius* Latreille) was the only seed-eating ant present. Ants were seen dragging seed 75 feet to a hill. With such

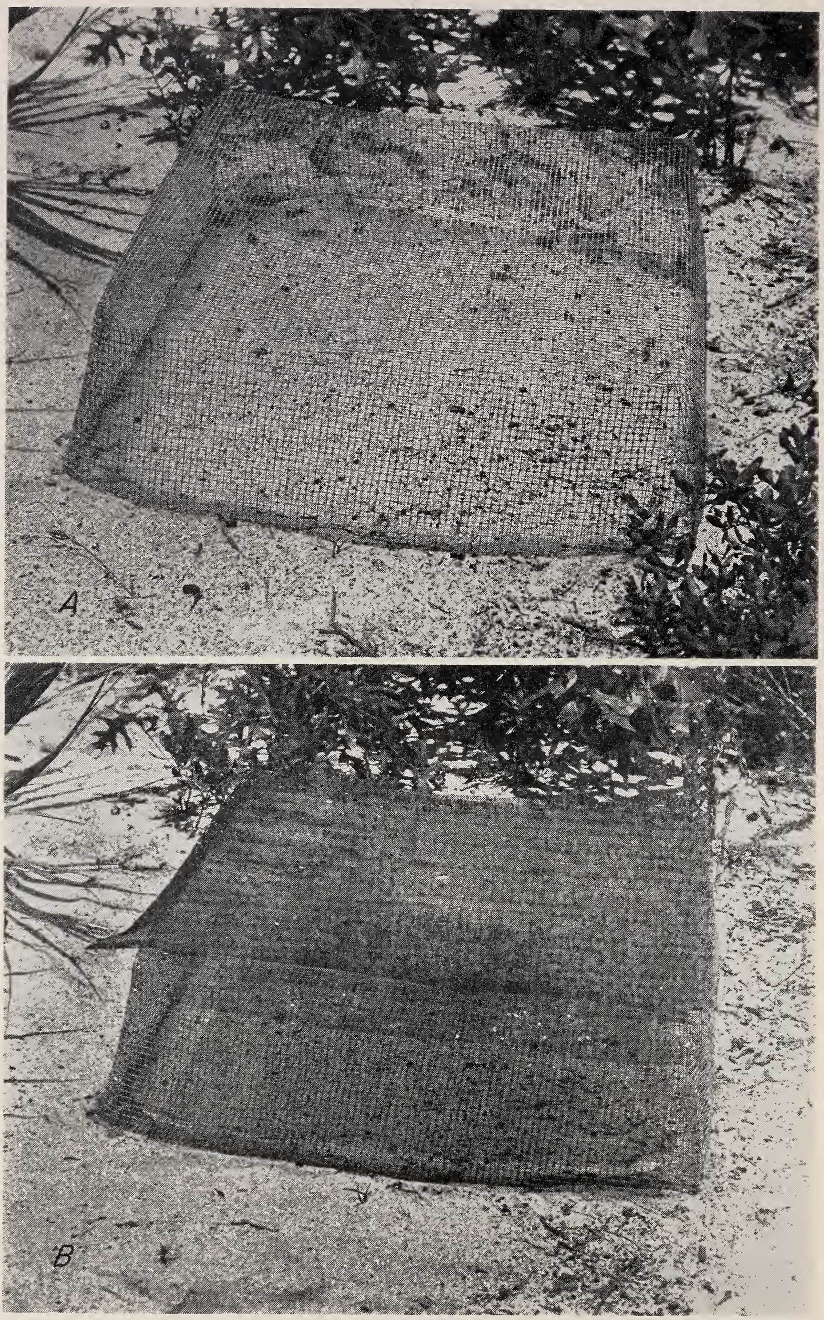

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FIGURE 9.—Plots protected from rodents and birds: *A*, Not shaded; *B*, shaded, with two layers of 16-mesh screen.

long-distance moving, a few colonies per acre could clean out a seed supply.

Without rodent and bird control, only 3 percent of the viable seed germinated. Germination was nine times greater where rodents and birds were excluded. Although both rodents and birds were excluded from the protected plots, the evidence of many seed hulls on the unprotected plots indicates that rodents rather than birds were largely responsible for seed losses. Two species of the white-footed deer mouse were trapped on the area and identified as Florida deer mouse (*Peromyscus floridanus* (Chapman)) and oldfield deer mouse (*P. polionotus* (Wagner)).

TABLE 2.—*Germination and survival of sand pine seed as affected by ant control and other variables*

Variable	Viable seed sown	Germination	Survival 1 year after sowing: Proportion of seeds sown	Survival 1 year after sowing: Proportion of seeds germinating
	Number	*Number*	*Percent*	*Percent*
No ant control (Block II)	9, 720	262	0. 6	23. 3
Ant control (Block I)	9, 720	2, 050	12. 3	58. 3
Degree of shade:				
Shaded	4, 860	1, 837	23. 7	62. 6
Unshaded	4, 860	213	1. 0	21. 6
Rodent control:				
Screened 1 year	3, 240	906	15. 4	55. 7
Screened during germination	3, 240	1, 034	19. 2	60. 2
Unscreened	3, 240	110	2. 1	61. 8
Surface:				
Bare mineral soil	3, 240	640	11. 8	59. 3
Pine litter	3, 240	834	15. 5	60. 2
Burned litter	3, 240	576	9. 7	54. 5
Season of sowing:				
Spring	2, 430	620	17. 4	68. 2
Summer	2, 430	839	13. 5	37. 8
Fall	2, 430	298	8. 0	65. 4
Winter	2, 430	293	10. 7	89. 1

Rodent control was apparently essential for appreciable germination but of little consequence in survival, since the survival of seedlings on plots where screens were removed was just as high as on plots where screens were left in place.

Effect of Shade and Litter Removal

A third condition essential for appreciable germination in this study was shade. Without shade, less than 5 percent of the seeds germinated. The primary effect of shade was a reduction in the frequency of lethal

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temperatures in the upper one-half inch of surface soil or in the litter layer. The lethal level for seedlings less than 1 year old is probably about 125° F. (*4*, *8*). Within the litter layer, temperatures exceeded this level during 8 months of the year (fig. 10). The shade used in this study reduced the litter temperature by about 25°, and this reduction was sufficient to maintain sublethal temperatures during all months except May and June.

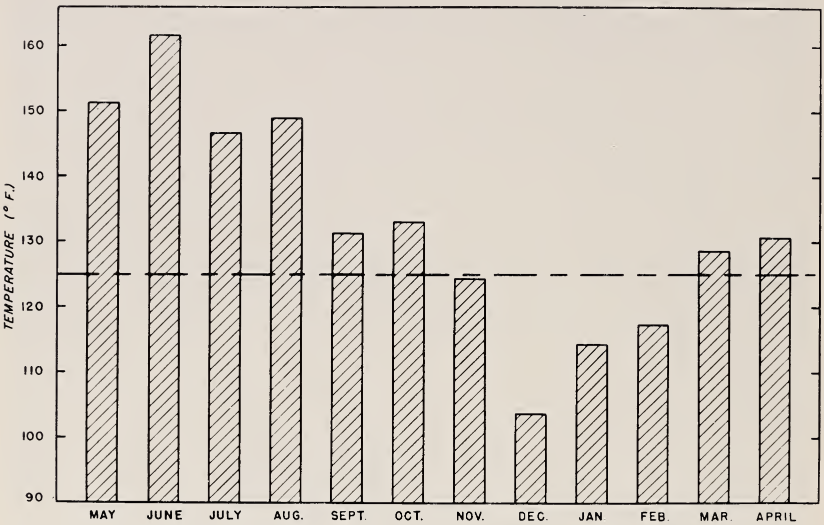

FIGURE 10.—Monthly maximum temperature within a litter layer for 1 year beginning in May 1950. Dashed line indicates approximate lethal temperature for pine seedlings. Temperatures in the upper one-half inch of soil were about 9° F. lower under burned litter and about 18° lower on bare soil than the temperatures shown here. Maximum temperatures occurred about 2 p.m.

Since the criterion of germination was emergence of the hypocotyl above ground, seeds with heat-killed radicles were never included in the germination counts, though seeds with shriveled radicles were frequently observed. Surface heat apparently was most damaging when the radicles emerged. This sensitivity of the radicle accounts for the very great difference in germination between shaded and unshaded plots.

Some seeds germinated without shade during periods of sublethal temperatures in the surface soil, but many of these were killed after emergence of the seedling. Lethal temperatures occurring after seedling emergence resulted in typical lesions at the ground line as described by Haig (*4*), and death of the seedling soon followed.

Removal of litter either mechanically by raking or by burning had no significant effect on either germination or survival on shaded plots. On unshaded plots, the number of surviving seedlings was too small to permit an analysis of variance.

Season of Sowing and Distribution of Rainfall

Ant control, rodent control, and shade are all essential for germination, and in the absence of any one of these factors very little germination occurred. The significance of season of sowing, however, was not apparent on inspection of the data.

The effect of season of sowing on germination was first tested in analyses of variance limited to data from shaded plots with protection from ants, birds, and rodents. Under shade, summer was the best season for germination. Either spring or summer sowing, however, resulted in better germination than fall or winter sowing. In a second test on unshaded plots, the combined germination from summer and fall sowings was significantly higher at the 1-percent level than that from combined winter and spring sowings.

For practical purposes, however, the total number of surviving seedlings is the best criterion for determining the effect of season of sowing. On shaded plots, this effect was not significant. On unshaded plots, however, there is some indication that fall sowing gives the best results, although, again, the number of surviving seedlings was too small to show significance.

For all sowing dates except the one in October, the period of most frequent germination coincided with a period of heavy rainfall (fig. 11). Although heavy rains (about 11 inches) fell on three successive days after sowing, only 10 percent of the total germination occurred in October. Germination of the October-sown seed was resumed toward the end of December after a longer period of frequent rains, and continued during January. Seed sown in January and April did not germinate in large numbers until June, when the summer rains began. Quickest and greatest germination occurred on the plots sown in July. Survival, however, was not good, because of high surface temperatures (fig. 12).

Studies of Soil Moisture and Soil Cover

The relationship between root penetration, soil cover, and soil moisture was studied on a cleared area adjacent to the germination and survival plots. Root penetration was quite rapid for each of the sowings; all germinating seed developed radicles at least 2 inches long within 10 days after emergence. An average 2-month-old seedling germinating in June and growing during the rainy season had a root nearly 8 inches long, or almost twice as long as the root of a 2-month-old seedling germinating in December or January and growing during the dry season.

The soil moisture content 2 inches below the surface, however, seldom reached the wilting point (0.63 percent)—a good indication that mortality of established seedlings on denuded sites can seldom be attributed to drought. On the other hand, the moisture content in the upper 2 inches of shaded and unshaded soil frequently went below the wilting percentage (table 3). A "t" test of the differences, however, showed that under shade, soil moisture in the upper 2 inches was not significantly higher at the 5-percent level than on unshaded areas. The poorer germination and higher mortality in the open (table 2), therefore, is probably a result of the higher surface soil temperature.

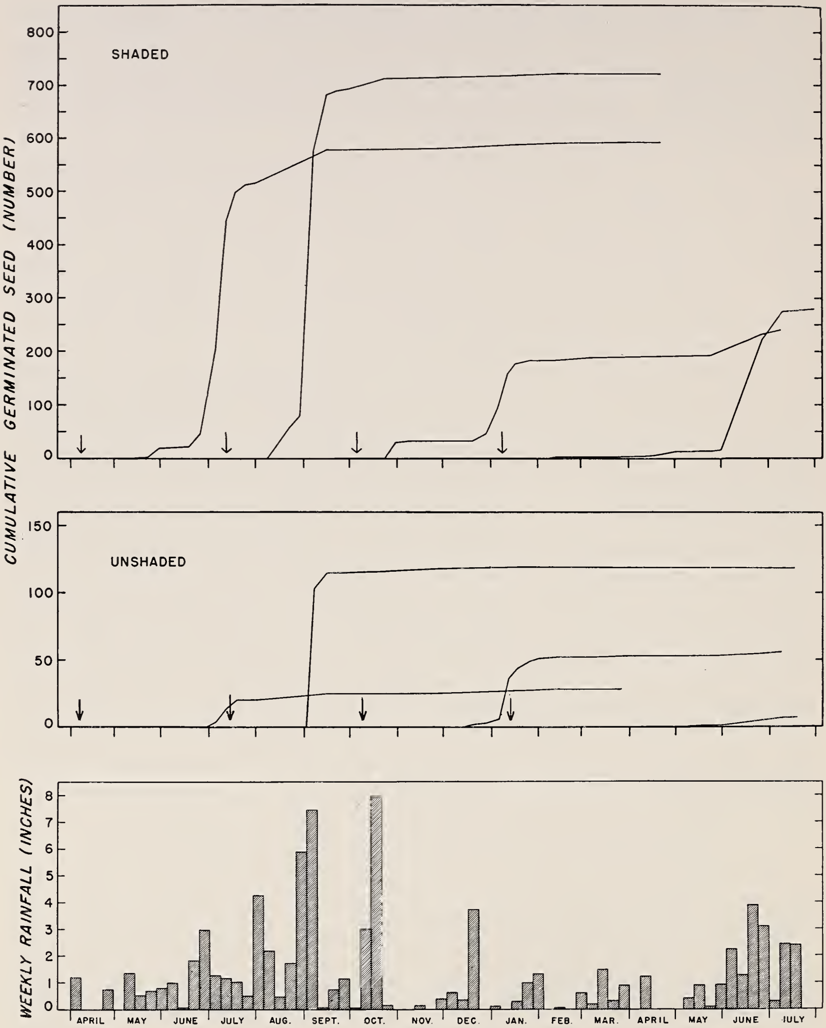

FIGURE 11.—Germination after each of four sowing dates as related to rainfall, 1950–51. (Arrows on base lines indicate sowing dates.)

A thin covering of sandy soil over the seed to a depth of about one-eighth inch was beneficial when sowing was done in April. Protection from ants, birds, and rodents was provided, but spots were not shaded. The mean cumulative germination curves for both surface sowings and covered seed sown in April of 1950 and 1951 are shown in figure 13. Rainfall during June, July, and August was plentiful

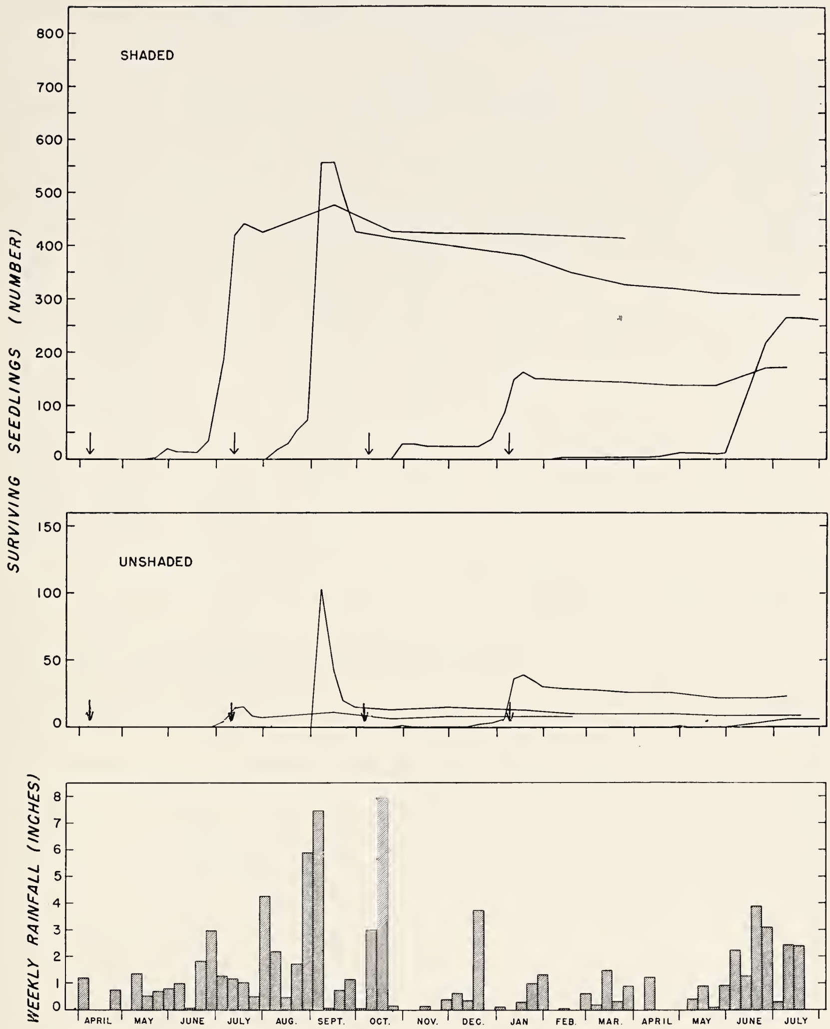

FIGURE 12.—Survival after each of four sowing dates as related to rainfall, 1950–51. (Arrows on base lines indicate sowing dates.)

in both years. Because of the high surface soil temperatures, very little successful germination occurred with seed either surface sown or covered during the summer.

Germination of most of the covered seed was delayed until October. The surface-sown seeds probably started to germinate during the wet summer months and were promptly killed by insolation.

TABLE 3.—*Soil moisture content, expressed in percent, at depths of 0–2, 2–4, and 4–6 inches in Kershaw fine sand*

Date of sampling	Soil depth in shaded plots			Soil depth in unshaded plots		
	0–2 in.	2–4 in.	4–6 in.	0–2 in.	2–4 in.	4–6 in.
1950:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Aug. 30	9.27	7.02	7.54	10.63	8.90	9.61
Sept. 12	4.04	4.14	3.38	1.01	3.28	3.45
Sept. 22	1.72	3.28	4.23	[1].45	1.18	1.65
Sept. 29	2.46	4.43	4.50	3.02	4.93	5.07
Oct. 9	2.40	3.20	3.69	1.94	2.97	3.25
1951:						
Jan. 17	1.58	3.60	3.92	.81	3.89	4.30
Jan. 31	.77	3.13	3.66	.71	3.22	3.68
Feb. 12	[1].53	3.69	3.66	[1].26	3.34	2.92
Feb. 23	[1].37	1.96	3.10	.66	1.32	1.86
Mar. 5	[1].58	1.49	2.97	[1].49	[1].61	1.47
Mar. 27	[1].37	2.60	3.73	[1].49	2.71	3.72
July 23	7.22	7.28	8.28	5.77	6.94	6.57
July 31	1.96	3.44	4.41	[1].46	3.29	5.01
Aug. 10	.71	3.79	3.90	[1].46	3.24	4.20

[1] Below wilting percentage.

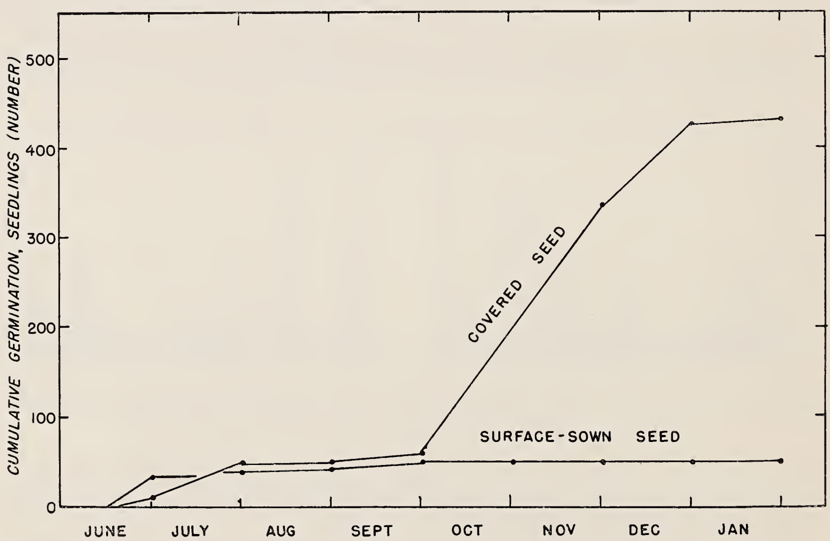

FIGURE 13.—Cumulative germination for seeds sown in April with and without a cover of fine sand and with protection from rodents, birds, and ants.

LARGE-SCALE TREATMENTS FOR INCREASING NATURAL REGENERATION

Tests described in the foregoing pages were small-scale and intensive. They showed that control of ants and rodents was essential to protect available seed, and that shade or other means of heat reduction were essential for germination and survival for almost all seasons of sowing. There were some indications that seedling establishment was also influenced by the time of seedfall and initial sprouting, but they were by no means decisive. And although the surface condition apparently had no statistically significant effect on germination and survival, the period of lethal surface temperatures can be shortened by exposing bare mineral soil.

The development of treatments for increasing natural regeneration in the field by modifying some of these controllable factors affecting germination and survival was the next problem. The areas involved were necessarily large, and replication was not usually possible. The results, therefore, can be considered indicative but not conclusive. Any combination of treatments was considered satisfactory if 400 or more milacres per acre were stocked with 1 or more seedlings 1 year old or older. Mortality after the first year was negligible. Large-scale tests were set up as follows:

1. Improving distribution of available seed by lopping and scattering branches from tops of harvested trees.
2. Destroying litter by prescribed burning or by ground scarification with a disk or a rolling brush cutter to reduce surface soil temperature and cover dispersed seed.
3. Control of seed eaters.
4. Determining best season of cutting for regeneration.

Increasing Seed Dispersal

The practice of lopping and scattering the branches from the tops of harvested trees is often used to reduce fire hazard in other regions, but this treatment serves another purpose in cutover sand pine stands because the cones on these tops hold a potential supply of viable seed for regeneration. Lopping and scattering help to bring about the greatest seed release in the shortest time.

Bunched tops are common on cutover areas because the crisscrossing of the stems eases the task of bucking pulpwood bolts (fig. 14), but this practice tends to concentrate the seed on spots that are unfavorable for germination. Such slash piles also create natural protection for seed-eating rodents.

Studies undertaken by the staff of the Ocala National Forest in 1948 showed that lopping and scattering after logging resulted in a 114-percent increase in the number of seedlings and a 92-percent increase in the number of stocked milacres per acre over that obtained on untreated tracts. The lopping and scattering treatment alone, however, was not sufficient to obtain the desired minimum of 400 stocked milacres per acre. Close inspection of slash treatment and resulting reproduction on these trials indicated a considerable variation between individual stands, treatment, and time of cutting.

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FIGURE 14.—A sand pine stand being clear cut for pulpwood.

Field studies installed in late winter and spring of 1951 to test variations of lopping and scattering were—

1. No treatment (check).
2. Pulling apart the tops.
3. Partial lopping and scattering, which consisted of lopping a few of the better cone-bearing branches.
4. Complete lopping and scattering.
5. Lopping and inserting the branches upright in the ground to facilitate seed dispersal.

Four replications were established in freshly cut stands.

Very few seedlings became established during the summer following treatment. Some germination and establishment occurred during the next fall and winter. The reproduction counts (table 4) were completed in May 1952. From the standpoint of cost and return, partial lopping and scattering was better than the other treatments.

In this study, as in the earlier tests made by National Forest rangers, none of the lopping and scattering treatments alone resulted in adequate regeneration. Partial lopping and scattering, however, was used effectively and economically along with ground scarification to obtain good seed dispersal, as described in the next section.

Improving Seedbed Conditions

Scarification of the forest floor to expose mineral soil offered excellent promise of getting a better seedling catch from a given quantity of seed. For example, adequate sand pine reproduction came in on a large tract that had been cut over, cleared, and disked for use as a bombing range during World War II. This same type of treatment has been successfully used to obtain natural regeneration on cutover stands of jack pine (*3*), which also has serotinous cones.

TABLE 4.—*Sand pine stocking with different methods of lopping and scattering, 1 year after treatment*

Treatment	Labor required per acre	Stocking	
		Seedlings per acre	Stocked milacres per acre
	Man-days	*Number*	*Number*
None (check)	0. 00	156	105
Tops pulled apart	. 61	144	103
Partial lopping and scattering	. 61	311	210
Complete lopping and scattering	1. 56	350	225
Inserting lopped branches	1. 24	361	190

The first study of disking as an aid to natural regeneration of sand pine was made in the fall of 1948. Adjacent 20-acre blocks were disked before and after cutting. Reproduction counts indicated fair stocking in some spots and inadequate stocking in others, but in general, disking before cutting resulted in two seedlings for every one obtained by disking after cutting. Scarification before cutting, however, is very difficult in well-stocked stands.

On October 14, 1950, three plots of about 2 acres each were scarified with a 2-ton Marden brush cutter. The number of seedlings and stocked milacres per acre on the untreated and scattered-branch plots were about the same as on other previous trials. Addition of the ground scarification treatment 2 weeks after the harvest cutting increased reproduction to almost the desired minimum of 400 stocked milacres per acre (table 5). A stocking of 600 stocked milacres per acre, obtained by scarifying 6 weeks after the harvest cutting, points out the effective time interval between harvest cutting and brush cutting at this time of year. Most of the cones were probably still closed 2 weeks after cutting, but had opened considerably after an in-

TABLE 5.—*Seedlings and stocked milacres 2 years after cone-dispersal and brush cutting-scarification treatments in October*

Cone dispersal treatment [1]	Ground scarification treatment	Stocking	
		Seedlings per acre	Stocked milacres per acre
		Number	*Number*
None	None	167	160
Branches scattered	None	362	230
None	2 weeks after cutting	681	375
Branches scattered	2 weeks after cutting	656	430
Branches scattered	6 weeks after cutting	1, 438	600

[1] Branches were scattered within 1 week after the trees were cut.

terval of 6 weeks; this deduction was substantiated by cone-opening data from earlier studies.

An Athens six-blade disk (fig. 15) has also been used for scarification. The disk is very effective where there is little ground cover, but the blades have a tendency to ride over thick brush piles and tops where the cones are concentrated, and little soil disturbance occurs. The rolling brush cutter, weighted with water, cuts through heavy slash and tops, but occasionally mats heavy needle litter. The disk did not appear to induce hardwood sprouting as readily as the brush cutter.

F–469245

Figure 15.—Ground scarification by disking on a cutover sand pine stand.

Prescribed fire has been used in the regeneration of sand pine, not only for the purpose of opening the serotinous cones, but for preparing the seedbed as well. An area of 40 acres of mature sand pine was clear cut for pulpwood in October 1947, and scheduled for prescribed backfiring. Favorable burning conditions, however, were not obtained until March 2, 1948, when the area was burned. While burning was in progress, the wind velocity increased to 15 miles per hour, shifted in direction, and changed the burn into a hot headfire. As a result, many cones and seed were probably consumed. Moisture conditions were favorable for germination in March, but April and May were extremely dry, and a summer reproduction count indicated only 7 stocked milacres per acre. Some germination and establishment occurred during the following fall and winter, but only 80 milacres per acre were stocked 3 years later.

The next attempt at backfiring was in August 1951 in a freshly cut stand, similar to the initial trial, with wind velocities of about 5 miles per hour 3 days after a good rain. Logging operations had disturbed what little ground fuel was present before cutting, and as a result the fire settled in the slash piles, where it consumed cones and seed. Many residual trees were killed by the fire. Because residual trees held a meager seed supply, and seeds on the ground were destroyed, reproduction on the area has been sparse.

A prescribed backfire prior to the harvest of a mature stand in September and October resulted in a clean seedbed and some hardwood control. A few individual trees were killed by scorch, but general observations indicated that the remaining trees were not damaged. Cones on the slash near the surface of the ground opened, seed were released, and germination followed during the winter months. One-year reproduction counts indicated that the plot supported approximately 1,618 seedlings per acre, with 640 stocked milacres per acre.

Headfires were also attempted in August 1951 under similar burning conditions in stands that were freshly cut, cut a year earlier, and cut 2 years earlier. About 30 residual trees per acre served as seed trees, although they had been left because of their unmerchantability rather than because of their seed-producing qualifications. The majority of the residual trees were killed by the headfire, which spread at a rate of about 30 chains per hour. The cones opened, and the seed was released. New seedlings appeared about 4 months after the burn, most of them in the vicinity of the better seed trees. One-year reproduction counts indicated adequate stocking (about 450 stocked milacres per acre) following headfires in the fresh cut and 1-year-old cut. Inadequate stocking on the 2-year-old cut may be a result of an insufficient number of cones on the residual trees. This point, however, was not checked with cone counts.

Several attempts at winter burning were made, but the fire would not carry even with the help of a flamethrower and a head wind. No information is available on other times of the year when fire can be used safely and effectively. As these tests indicate, prescribed burning in the sand pine type is still purely experimental, and its use is not recommended at this time.

Controlling Seed Eaters

Observation and small-scale trials had shown that the Florida harvester ant feeds extensively on sand pine seed; the ants of three anthills per acre are enough to clean an area of available seed. Their distribution in the sand pine type, however, is erratic and usually confined to cutover areas.

The first field trial of ant control consisted of 1-acre plots established on a scarification study site. Ant control consisted of spreading 5 percent chlordane dust uniformly over the area at the rate of 5 pounds per acre. The scarified ant control plots had 71 percent more seedlings and 42 percent more stocked milacres per acre than the larger scarified blocks without ant control (table 6). Observations on the entire study area, however, indicated a low ant population, so the chlordane may have had an effect on other biotic agents in addition to its control of ants (*6*).

TABLE 6.—*Effect of scarification, scattering the cone-bearing branches, and ant control on the stocking of cutover areas*

Treatment	With ant control [1]		Without ant control [2]	
	Seedlings per acre	Stocked milacres per acre	Seedlings per acre	Stocked milacres per acre
	Number	*Number*	*Number*	*Number*
Scarification after lopping	2, 306	660	1, 250	410
Scarification before lopping	1, 931	550	1, 231	450
Lopping and scattering	331	220	250	160
None (check)	----------	----------	150	110

[1] Areas were 1-acre blocks at the center of 20-acre treatment blocks.
[2] Areas were 20-acre blocks.

The second field trial with varying degrees of ant control was incorporated in another scarification study in the spring of 1952. Although some stocking increases were found where ant control was employed, reproduction was not significantly better than on areas without ant control (table 7).

The scarification study of 1952 also included some large-scale comparisons of rodent populations. Oat seed treated with thallium sulfate was distributed on 150 acres of the area prior to cutting. Saturation trappings, consisting of 360 trap-nights per acre extending over a period of 5 consecutive nights on 1-acre plots in each area, showed the mouse population on cutover areas to be about twice that on uncut tracts. The release of seed on cutover areas probably attracted rodents (fig. 16) and resulted in a population buildup. The thallium sulfate treatment reduced the number of mice to less than one-third of the initial population, as estimated by the number caught (table 8).

The effect of rodent control in addition to seed distribution, scarification, and ant control was studied on this same area. Cutting was begun in December 1951 and was completed in April 1952. Scarification treatments were carried out during February, March, April, and

TABLE 7.—*Effect of rodent control methods with and without scarification and with three degrees of ant control*

Degree of rodent and ant control	Ground scarified		Not scarified	
	Seedlings per acre	Stocked milacres per acre	Seedlings per acre	Stocked milacres per acre
Rodent control:	*Number*	*Number*	*Number*	*Number*
None	954	500	365	230
Hills dusted	1, 037	440	498	250
Area dusted	1, 411	565	481	280
No rodent and no ant control	----------	----------	156	110

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FIGURE 16.—White-footed deer mouse eating sand pine seed.

May of 1952, about 8 weeks after cutting, and were followed with a second dose of poison grain.

Germination was first observed in April 1952. Several hundred seedlings were staked; only a few were still living in July 1952, and very little germination was observed during the rest of the summer. Germination was resumed late in October and continued throughout the late fall and early winter. Mortality during this period was low. Reproduction counts in April 1953 (table 7) indicate that scarification and rodent control had a greater effect than ant control on sand pine seedling establishment.

TABLE 8.—*Effectiveness of oats treated with thallium sulfate in reducing mouse populations in cut and uncut stands*

Stand condition	Date of trapping	Not poisoned		Poisoned	
		Trap-nights [1]	Mice caught	Trap-nights [1]	Mice caught
		Number	*Number*	*Number*	*Number*
Uncut:					
Open ground cover	February 1952	330	3	248	0
		318	1	254	0
Heavy ground cover	February 1952	287	3	259	3
		309	1	261	0
Cutover	April 1952	281	4	297	1
		288	5	309	1
Totals			17		5

[1] Corrected by deducting number of sprung traps and number where bait was removed.

Time of Cutting Influences Regeneration

On cutover areas, time of cutting determines time of seed release, which is equivalent to time of sowing. Without other supplemental treatment, more seedlings were obtained after summer and fall cuttings than after winter and spring cuttings (table 9), but stocking was not adequate in either case.

With ground scarification, much better stocking was obtained after both spring and fall cutting than without scarification. Fall was still the better season for cutting, with a stocking 20 percent greater than spring cutting, even though rodents were poisoned after the spring cutting and were not poisoned after the fall cutting.

Table 9.—*Effect of cutting period and certain supplemental treatments on regeneration of cutover areas*

Season of cutting	Scarification	Area	Stocking: Seedlings per acre	Stocking: Stocked milacres per acre
		Acres	*Number*	*Number*
July–November 1951	None	40	500	300
February–April 1952	None	20	156	110
October 1952	None	10	167	160
February–April 1952 [1]	None	20	365	230
February–April 1952 [1]	April–June 1952	60	954	500
September 1950	October 1950	3	1, 438	600

[1] Rodent control used.

ARTIFICIAL REGENERATION

Planting

Although sand pine areas have been considered poor planting sites because of past planting failures, some form of artificial reforestation is necessary if the 30,000 acres in the Ocala Forest without a seed source are to be productive again.

Monthly plantings of 1–0 wildling stock were first tried during the winter of 1950–51 from October through February. Survival was less than 20 percent for each of the monthly plantings; the seedlings usually died within 3 months after planting. Sand pine seedlings are apparently very sensitive to the shock of transplanting, and root disturbance has even occasionally resulted in the death of otherwise healthy, mature trees. The development of an extensive root system in the nursery and greater care in lifting and handling seedlings may help to reduce the shock of transplanting and consequent mortality.

Custom-grown seedlings were raised in Florida's Olustee Nursery in 1953 for a second planting study. All necessary precautions to prevent drying were taken from lifting time to planting, and although

the seedlings were only about 4 to 5 inches tall, they appeared vigorous and healthy. About 15,000 seedlings were planted on typical, poorly stocked, cutover sand pine areas of the Ocala National Forest in both November and December of 1953. Half the seedlings were planted by machine and half by hand. The December plantings survived significantly better than November plantings, but there were no significant differences between hand and machine plantings. Survival after 6 months, which embraces the heavy mortality period, averaged 49.6 percent and varied as follows:

	Survival	
	Hand planted (percent)	*Machine planted (percent)*
Plantings:		
November	44.2	44.1
December	57.7	52.4

Another trial was made to test the benefits of extensively developed root systems by applying shade and/or fertilization in the nursery bed. In December 1955, 1–0, 1½–0, and 2–0 stock subjected to these treatments were planted on a denuded sand pine site. The effect of nursery bed shading on the improvement of outplanting survival was significant at the 1-percent level; that of nursery bed fertilization at the 5-percent level. Survival of the 1–0 stock (71 percent) was far superior to the 1½–0 (20 percent), or 2–0 stock (5 percent) 6 months after planting. Apparently there is a close relationship between the survival of outplanted sand pine seedlings and their ratios of top length to root length. On 1–0 seedlings, root length was equal to or greater than top length, and survival was good. After lifting, root length on the 1½–0 and 2–0 seedlings was less than two-thirds of their top length, and survival was poor, in spite of the care used to retain as much of the root system as possible.

Direct Seeding

Direct seeding is less expensive than planting, but because of the many failures encountered with seeding trials of other southern pine species in the past two decades, planting has generally been preferred as a means of artificial reforestation (*2*). Evidence from small-scale germination and survival studies, however, indicated that seeding might be practical in the Big Scrub if adequate protection from seed-eaters was provided.

Two promising leads on effective chemicals for use as rodent repellents and poisons were reported by Spencer (*9*) : "castrix nitrate" (the nitrate salt of 2-chloro 4-dimethylamino 6-methyl pyrimidine) and "tetramine" (tetramethylene disulpho tetramine). Castrix nitrate was first tested in the fall of 1951 in conjunction with a prepoisoning treatment of oat bait coated with thallium sulfate. Both the bait and the treated seed were prepared by the Denver Wildlife Research Laboratory, U.S. Fish and Wildlife Service, Denver, Colo., and sown on a 40-acre block in the Ocala Forest.

The sand pine seed was distributed with a Baker seed spotting tool (fig. 17) adjusted to drop five seeds per spot at a depth of about one-fourth inch below the ground surface. Seed spots protected with

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FIGURE 17.—A Baker seed planter used for seed spotting. The container at the top holds the seed; as the handle is depressed, a notched rod rises within the container, bringing seed up and depositing it in a tube going to the ground. Further pressure on the handle pushes the seed into the ground.

conical screens, in addition to untreated seed sown in unprotected spots, were used for check plots. An innovation included in this test was the use of freshly collected, unopened cones in spots protected with conical screens.

Chlordane was used for ant control over one-half of the plot where the castrix nitrate-treated seed were sown, but ant control had no appreciable effects on the results.

Germination began in November and continued until February. None of the control measures, however, provided complete protection against the seed-eating rodents. Mechanical protectors (fig. 18) were effective as long as they remained in place, but many were removed by unknown agents. The other control measures of chlordane, poison bait, and repellent seed coatings gave little protection, and stocking percentages were extremely low 6 months after sowing:

Treatment:	*Stocking percentage* [1]
Untreated sand pine seed	3
Prepoisoning with thallium sulfate-treated oats, then seeding with untreated sand pine seed	2
Castrix-nitrate treated sand pine seed	2
Screens over seed spots	[2] 38
Screens over sand pine cones	[3] 66

[1] Spots with 1 or more seedlings, expressed as a percentage of the total number of spots sown.

[2] Figure based on spots where screens remained in place, which was 69 percent of the total number sown. The screens were removed by unknown agents from the other 31 percent.

[3] Figure based on spots where screens remained in place, which was 61 percent of the total number sown. Screens were removed from the remaining 39 percent of the spots.

Although some early seedling mortality was evident, it did not appear to be a limiting factor. These failures, however, do not preclude the possibility that effective control of rodents might be obtained by refinements in the procedure for use of thallium sulfate baits or by refinements in the treatment of sand pine seed with castrix nitrate.

The improved stocking percentages obtained by the use of mechanically protected cone and seed spots led to a second field trial. In June 1952 a test was set up to compare the effectiveness of paper drinking cups and conical screens as protectors, and to compare cones with seeds for the seed supply in the spots. Three blocks of denuded cutover land were selected for the study site, marked off into 4 plots each 2 acres in size, and seeded at the rate of 200 spots per acre. Pine cones from the 1951 crop were used for the cone spots, and at least 2 sound sand pine seed were sown on each seed spot.

Some germination and establishment occurred during the summer of 1952. A September inspection indicated that stocking was better on the seed spots than on the cone spots, and better under cup protection than screen protection. The final inspection in April 1953 showed the same general trend:

Treatment:	*Average stocking* *September 1952 (percent)*	*April 1953 (percent)*
Cups over cones	4.3	18.7
Cups over seed	36.0	37.3
Screens over cones	3.0	14.3
Screens over seed	12.3	22.7

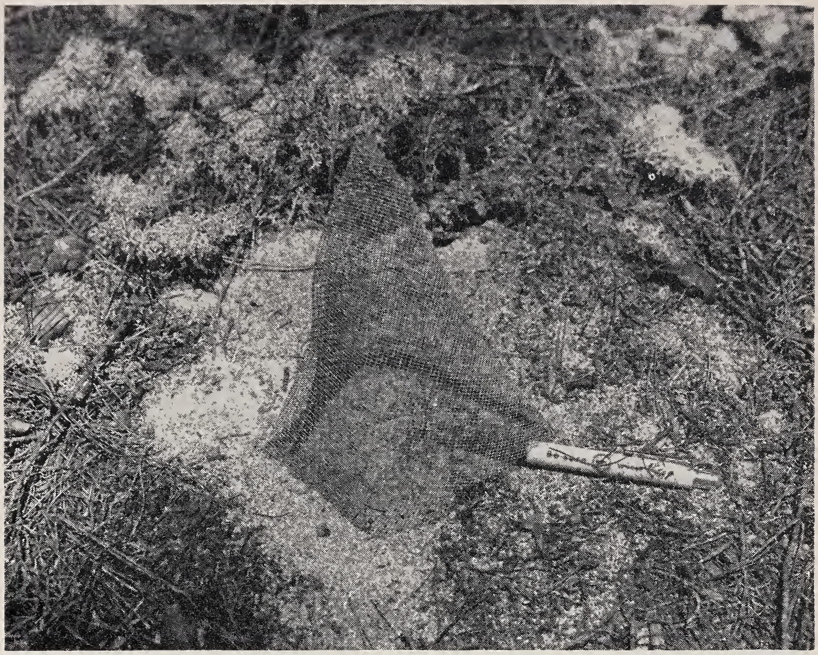

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Figure 18.—Seed spot protected with a conical 16-mesh screen.

The stocking percent of the cone spots had increased considerably since the first inspection, indicating that many of the cones had probably released their seed slowly and germination thus did not occur until winter. None of these direct seeding treatments, however, can be considered successful.

Another direct seeding trial was made in the fall of 1952 to compare the relative effectiveness of tetramine and castrix nitrate for rodent control. One batch of sand pine seed was soaked in a 1-percent solution of tetramine in acetone and another batch in a 1-percent solution of castrix nitrate in water. Soaking time on each batch was 1 hour, as prescribed by Spencer.[8]

Petri-dish germination tests showed the following effects of these treatments on viability of the seed:

Treatment:	*Percent viable*
Untreated	52
Tetramine	39
Castrix	41

Random samples were selected in each seeding area, and individual seed spots were staked and observed for 6 months. The first inspections seemed to indicate adequate rodent protection, inasmuch as the seed were intact 3 weeks after sowing. Subsequent checks, however,

[8] Personal communication from Donald A. Spencer, Denver Wildlife Research Laboratory, Fish and Wildlife Service, U.S. Department of the Interior.

revealed that this protection was shortlived, for many of the seed were consumed by rodents and birds when germination first started. None of the seeding treatments in this trial resulted in adequate seedling establishment.

DISCUSSION AND RECOMMENDATIONS

Timing appears to be of utmost importance in the regeneration of sand pine. Germination may occur at almost any time of the year, but if new seedlings sprout in the field during the months of February, March, April, or May, they are usually killed by heat and drought shortly thereafter. Summer germination is subjected to the same heat conditions, but those seedlings that have some shade will also have the benefit of normal summer rains and will usually survive the critical establishment period. Seedlings that germinate in the fall and early winter, however, generally have the best chance for successful establishment. Surface temperatures are favorable, moisture conditions are seldom critical for any extended periods of time, and the seedlings are usually sturdy enough to withstand the ravages of the next spring season. The most favorable germination and establishment period in the field apparently extends from about October 15 through January 15.

Sand pine seed trees, literally speaking, are rare in central Florida. Only after a tree is harvested and the cones are subjected to reflected heat from the ground does the seed supply become available. The season of the year most favorable for cone opening, unfortunately, does not usually coincide with the best time for germination and survival. The time of cutting, therefore, is an important consideration in the harvesting and natural regeneration of sand pine stands. If a stand is cut in late winter or early spring, the cones will open at the first sign of warm weather, the seed will fall, and if moisture conditions are favorable, germination will follow. Observations have shown, however, that this kind of regeneration fails because of the heat and drought conditions that almost always occur sometime in the spring or early summer. If a stand is cut during the summer or fall months, cone opening and seed release may not be as rapid or plentiful, but it is usually adequate and coincides with a favorable establishment period. Midwinter harvests generally result in retarded cone opening and seed release because of the relatively low surface temperatures at that time of year. Germination and establishment, consequently, again occur during poor conditions. The most important consideration in the timing of harvest, therefore, is to get rapid and plentiful cone opening as soon as establishment conditions are advantageous.

When winter and spring cutting is unavoidable, some way of delaying germination is essential if satisfactory regeneration is to be obtained. Cone opening during the spring is difficult to retard, but a light covering of soil over the seed provides some protection from the high surface soil temperatures and usually defers germination until the fall season. The soil covering also provides some protection against seedeaters, particularly birds. Ground scarification, therefore, is of considerable benefit on cutover sand pine stands, and especially on those cut in the winter and spring.

Rodents, birds, and ants constitute no problem after seedling establishment; if an adequate seed supply is available along with proper seedbed conditions and timing of the cut, their effect on natural regeneration is usually minimized. Harvester ant depredations may, on occasion, be severe in small portions of cutover areas; ant hills, and consequently ant populations, are quite heavy in some areas but very light or lacking in others.

One of the most encouraging phases of the sand pine regeneration story is the pattern of stocking buildup that follows cutting. Contrary to the pattern of many other species, the number of sand pine seedlings per acre and their distribution usually improve for several years following harvest. Since evidence indicates that seed seldom germinate later than a year after release, this stocking improvement is probably a result of continuing cone opening, extended over a period of several years. Artificial reforestation, therefore, should not be prescribed for cutover tracts until several years have elapsed since cutting, and a careful examination indicates that stocking is still inadequate.

The preceding studies provide some tentative recommendations for increasing natural regeneration of sand pine after cutting in the Ocala National Forest and peninsular Florida:

1. Mature sand pine stands should be clear cut to a minimum merchantable diameter limit. The period extending from June to December is preferred for cutting.
2. Areas tractor logged during this period need not be given further treatment.
3. Ground scarification with a disk or brush cutter is recommended on cutover areas where tractor logging is not used. The best time interval between cutting and scarification has not been worked out for all months of the year, but the intervals listed in table 10 are the best estimates that can be made at present.

TABLE 10.—*Recommended time interval between cutting and ground scarification for each month of the year, with reliability of estimate* [1]

Month of cutting	Optimum		Minimum		Maximum	
	Months	*Reliability index*	*Months*	*Reliability index*	*Months*	*Reliability index*
January	4	C	3	B	8	C
February	3	B	2	B	7	C
March	3	B	2	B	6	C
April	2	B	2	B	5	C
May	2	B	2	B	5	C
June	2	B	1	B	4	C
July	1½	A	1	A	4	C
August	1	A	1	A	4	C
September	1½	A	1	A	3	C
October	1½	A	1	A	3	C
November	2	C	1	B	--------	D
December	5	C	1	C	9	C

[1] Reliability index: A, data from actual test; B, deduction from tests on cone opening and from germination and survival study; C, deduction from general observations; D, no information.

4. Where more than two hills per acre of Florida harvester ants occur, 5 to 10 pounds per acre of a 5-percent chlordane dust should be applied after ground scarification. This dosage is sufficient for complete ground coverage.
5. Ground scarification should be supplemented by partial lopping and scattering of cone-bearing branches. A three-man crew is suggested for lopping and scarification.
6. Cutover areas that have less than 300 stocked milacres per acre 3 years after cutting should be planted with 1–0 sand pine stock.

SUMMARY

The serotinous nature of the cones of sand pine, limited soil moisture, high surface temperatures, and seed losses to predators have all restricted adequate regeneration of this species over its range in central Florida. Stands in the past regenerated from wildfires, but the standing trees were usually killed and only a small part of the merchantable timber could be salvaged. When merchantable stands of sand pine on the Ocala National Forest were first harvested for pulpwood (1940–50), they seldom regenerated adequately.

Natural seedfall from standing trees is meager unless the trees are killed by fire. The cones on the tops of harvested trees, however, opened when they were brought within 2 feet of the ground during 8 months of the year (April–November). Although some viable seeds are obtained from cones up to 5 years after maturity, the fresher cones provide the bulk of viable seed for regeneration.

In a small-scale test under controlled conditions, shade and protection from rodents, birds, and ants were essential for appreciable germination and survival. Only 1 seed germinated in full sunlight for every 9 that germinated under shade; more than 20 times as many seedlings became established under shade as in full sunlight. Approximately 10 times more seeds germinated under rodent and bird protection than without protection. A similar trend was evident where ant control measures were applied, although subsequent studies showed that local ant populations large enough to destroy appreciable quantities of seed are rare.

The principal seed-eating fauna were identified as the Florida harvester ant and the white-footed deer mouse. Seed-eating birds were mostly mourning doves and chewinks.

Under shade, greater germination and survival were obtained from spring and summer sowings than from fall and winter sowings. Without shade, very few seeds germinated; more 1-year-old seedlings were produced after summer and fall sowings than after winter and spring sowings.

Under shade and with protection from ants and mice, germination was about equal on litter, burned litter, and bare sand surfaces. Survival, however, was somewhat better on the litter surface than on the burned surfaces.

Temperatures lethal to newly emerged seedlings (above 125° F.) were recorded during 8 months of the year within the litter layer without shade. Soil temperatures in the upper one-half inch under a burned surface were about 9° cooler, and under the bare sand were about 18° cooler than in the litter layer.

A series of large-scale tests was made to develop practical methods for regeneration of cutover areas where shade could not be provided. Preliminary studies had shown that seeds sown just below the surface of the soil escaped the effects of high surface temperature.

Clear cutting in the summer and fall, followed by mechanical ground scarification and partial lopping and scattering of cone-bearing branches from the tops of harvested trees, usually resulted in adequate reproduction, which was arbitrarily set at 400 or more stocked milacres per acre. Use of tractors for skidding logs during the cutting operation also provided adequate ground scarification.

Clear cutting in the late winter and spring resulted in much lower germination and survival. Control of ants with a chlordane dust and control of rodents with a thallium sulfate bait combined with ground scarification compensated to some extent for the low germination and survival and resulted in barely adequate stocking on one area cut over during the period February to April 1952.

Prescribed burning with a cool backfire prior to clear cutting an area in the fall resulted in more than 600 stocked milacres per acre without further treatment. Headfires in freshly cut tracts gave rise to adequate stocking where sufficient seed-bearing trees remained after the harvest. Under prevailing ecological conditions, however, the sand pine type is usually explosive. The prescribed conditions for burning to obtain regeneration, therefore, rarely occur.

Nursery-bed shading and fertilization increased the survival rate of outplanted sand pine seedlings significantly. Survival of 1–0 stock (71 percent) was much better than that of older stock (20 percent), particularly when the roots were longer than the tops.

Direct seeding trials were unsuccessful. The loss of seed to rodents, birds, and ants was the largest single obstacle to this method of artificial regeneration.

Proper timing is of great importance in obtaining adequate natural regeneration. Clear cutting in summer and fall, followed by some form of ground scarification and partial lopping and scattering of cone-bearing branches, is recommended.

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